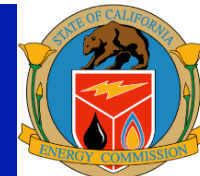# Greenhouse Gas Emissions Estimates from One Year of Measurements at Two Towers in Central California and Complementary Aircraft Measurements

CEC Annual 20090910

M.L. Fischer (mlfischer@lbl.gov), C. Zhao - LBNL

A. Andrews, L. Biacno, E. Dlugokencky, A. Karion, S. Montzka, C. Sweeney - NOAA Earth System Research Laboratory
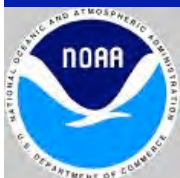
S. Surapali, T. Sherwood - Kalscott Engineering

D. Day, I. Faloona - UC Davis

J. Eluszkiewicz, T. Nehrkorn - AER Inc.

C. MacDonald - STI Inc.

Outline

- Overview of California's GHG Emissions
- The California Greenhouse Gas Emission Measurement Project (CALGEM)
- CH_4 Emissions Estimates for Central CA
- Design of a Regional GHG Emissions Measurement Network
- Airborne Greenhouse Gas Survey project (AGES)
- Conclusions

California GHG Emissions

- Non-CO$_2$ GHG emissions comparable to CO$_2$ but…
  - Largely from biological sources and not readily metered
  - Uncertainties in inventories are large
- Atmospheric inverse approaches provide independent check

CA GHG Emission Trends
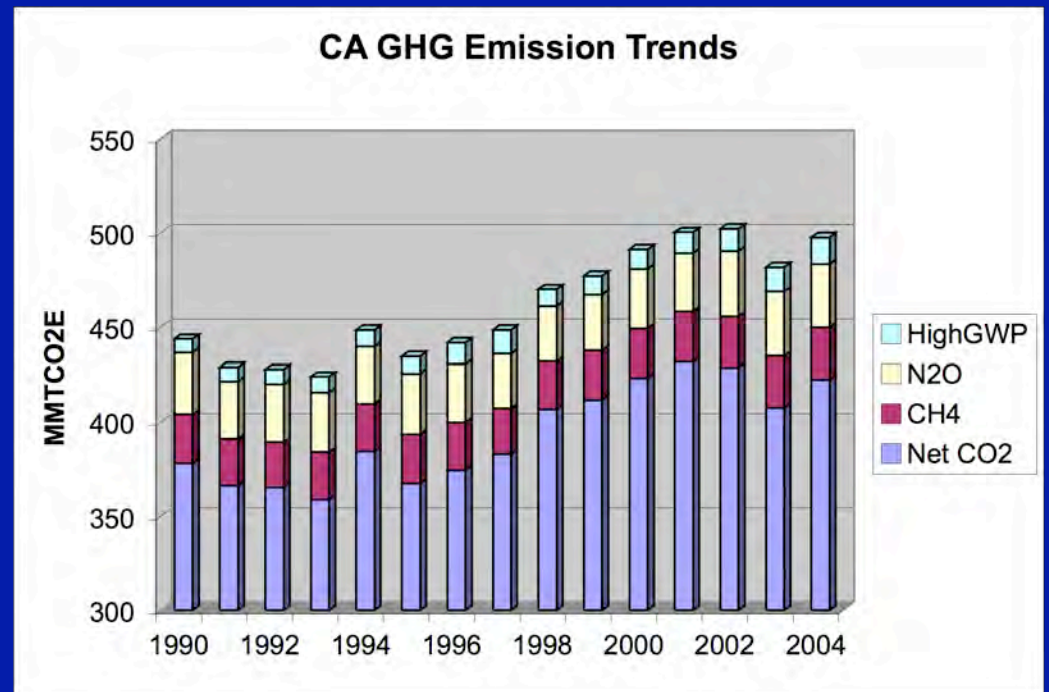
CEC, 2006

CEC, 2006 ; USEPA, 2007

LBNL-NOAA Collaboration: California Greenhouse Gas Emissions Measurement Project (CALGEM)

Sutro Tower (232 m agl)
Oceanic + urban

Walnut Grove (483 m agl)
Central Valley + Bay Area

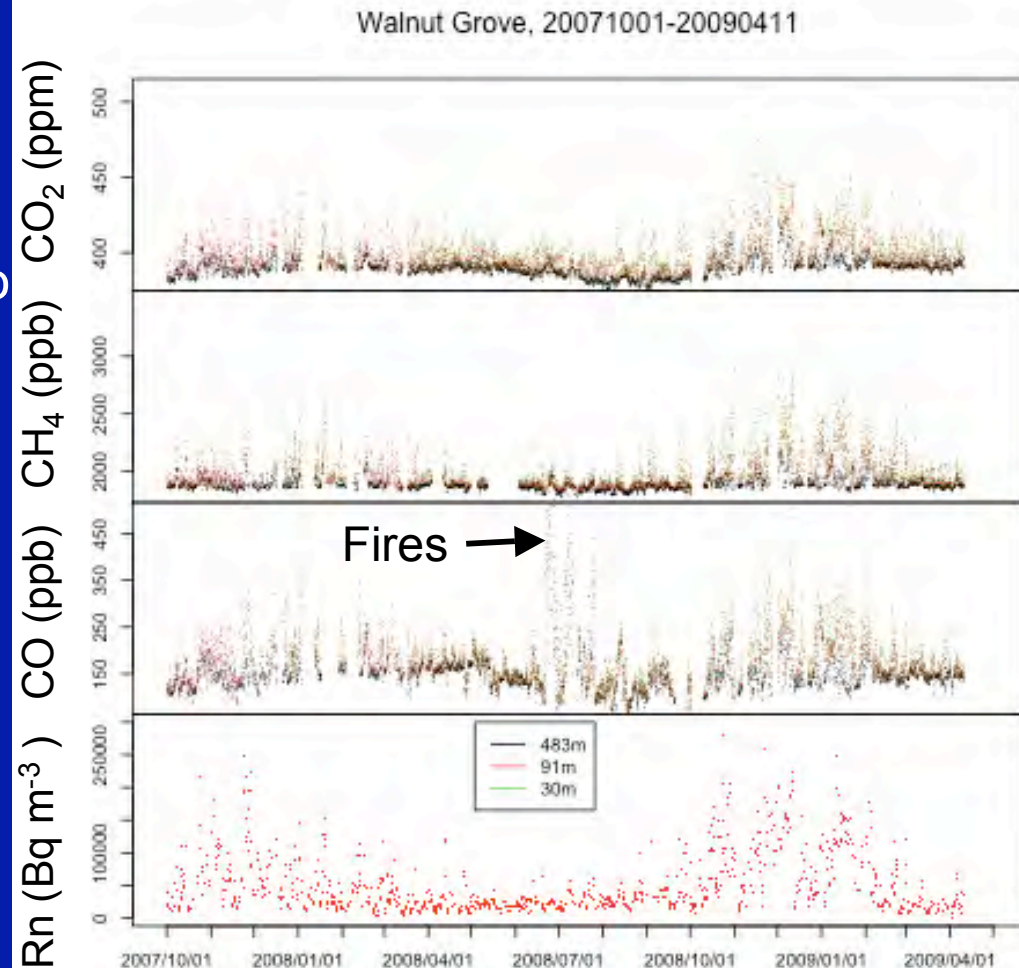in situ CH_4, CO_2, CO, ^{222}Rn
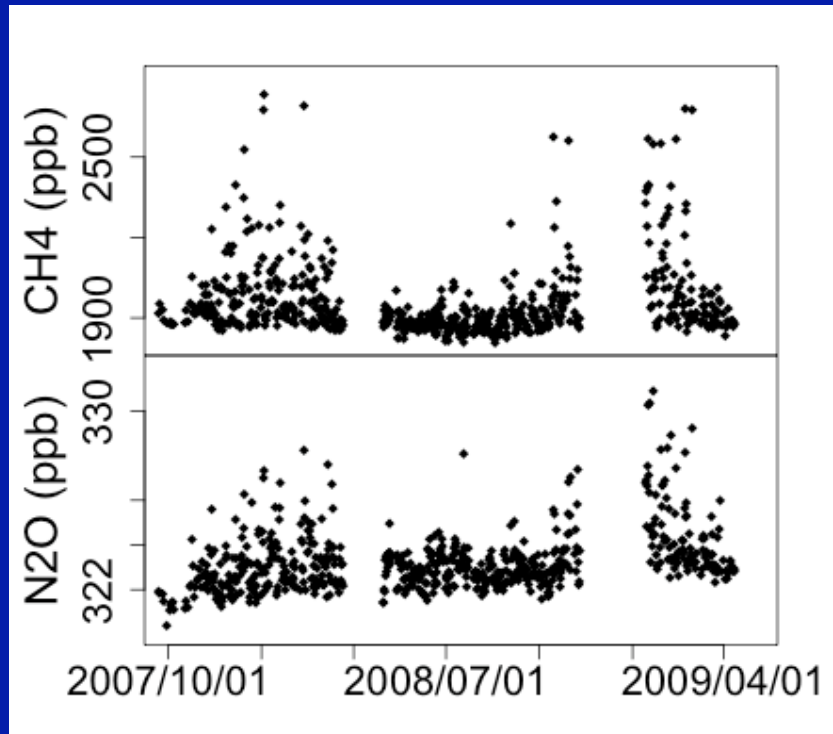
Daily Flasks

115 km

lat 37.876289°   lon −121.525128°
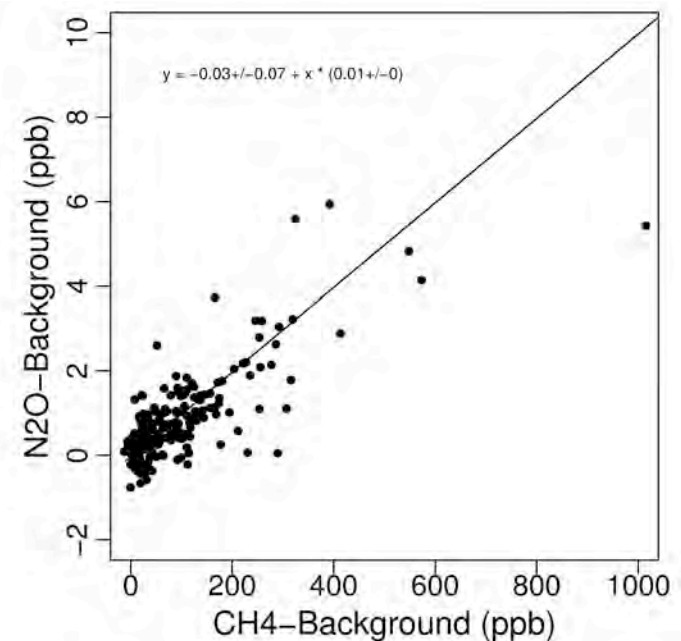
1.5 yr Measurements at Walnut Grove

- Impact of regional emissions are clearly visible in measured data
- Strong diurnal cycles due to boundary layer mixing variations
- Seasonal cycles due in emissions and boundary layer mixing

Walnut Grove, 20071001-20090411

Focus on Walnut Grove CH$_4$ and N$_2$O

Fall-Winter (Oct - Dec, 2007)
WGC 91 m, Well Mixed, 1400 Local

- CH$_4$ and N$_2$O share similar patterns (both dominated by valley emissions)

a priori CH$_4$ Flux Maps

- Crop Agriculture (Salas)
- Landfill (point sources)
- Livestock (USDA)
- Natural gas dist./use
- Petroleum refining and use
- Wetlands (Potter et al.)
- Above sum to CA-specific
- EDGAR3.2 (1x1degree)
  - Landfills and petroleum extraction and refining ~ 2 x CA estimates
- Also: regional subdivision for spatial analysis
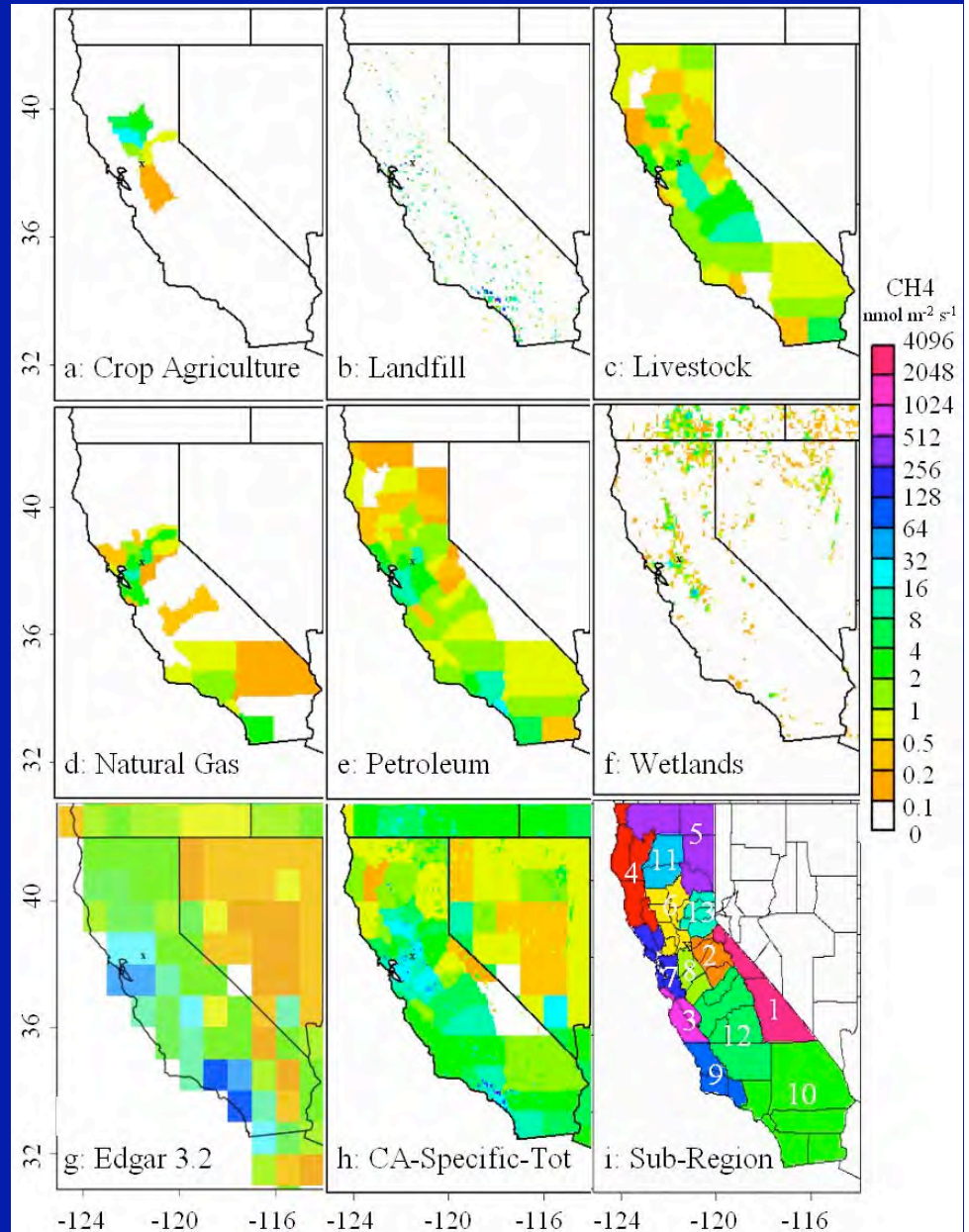
WRF-STILT Footprints for WGC Tower

- WRF meteorology:
  - Nested grids (40,8,1.6 km)
  - NARR boundary forcing
  - Hourly averaged fields
- Example of average footprint for Oct-Dec, 2007 from hourly maps
- Largest surface influences (purple) for Bay Area and Central Valley
- Predict CH_4 signal =

  F_{CH4} * footprint +

  Marine Background
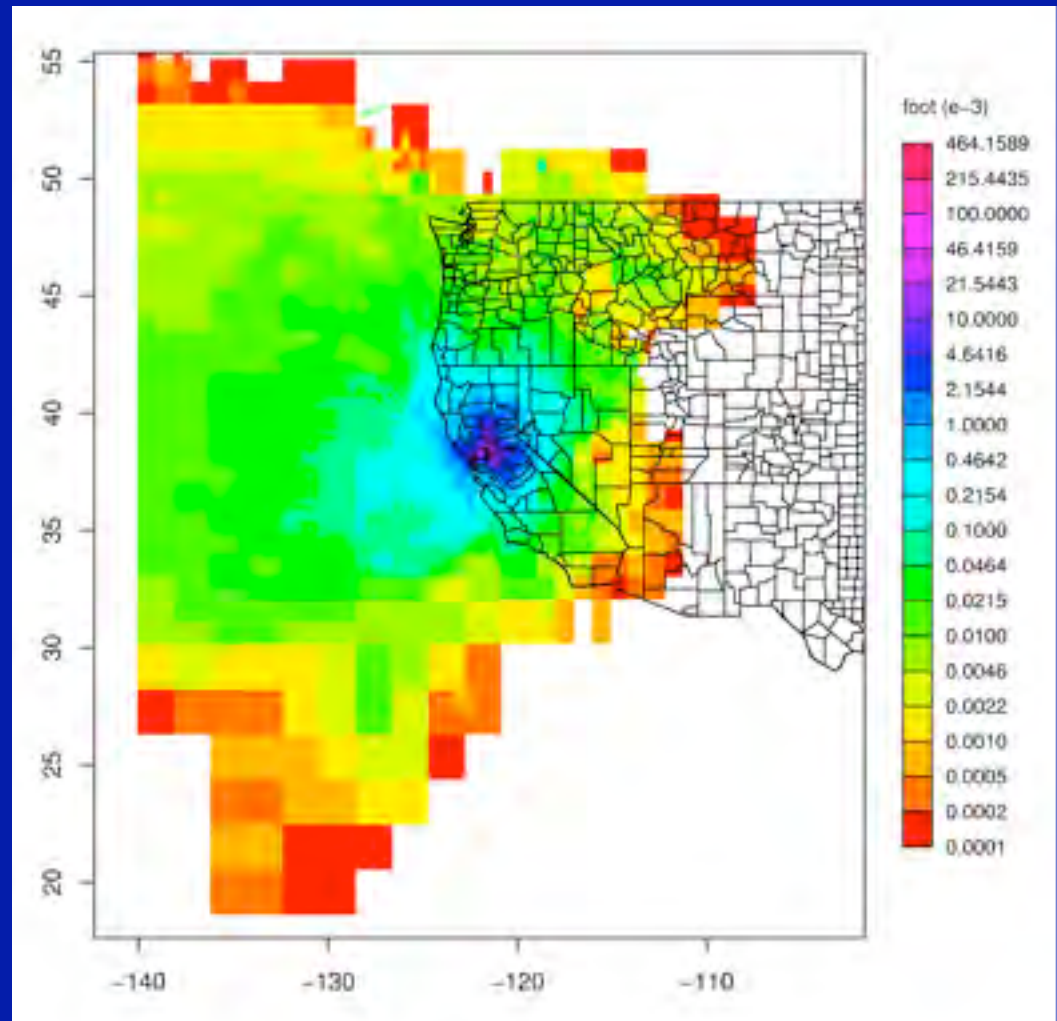
Uncertainty Estimates

- Error sources are quantified

- Errors are propagated through modeling system to provide quantitative uncertainty in estimated emissions

  – Boundary layer ~ 25 %

  – Wind Velocity ~ 10%

  – GHG background ~ 15 %

 – Inventory resolution ~ 8 %

  – Other ~ 8%

- Quadrature sum ~ 32%

$y = -138.16 +/- 69.62 + x * (1.25 +/- 0.1)$

483 m WGC

NOAA MBL
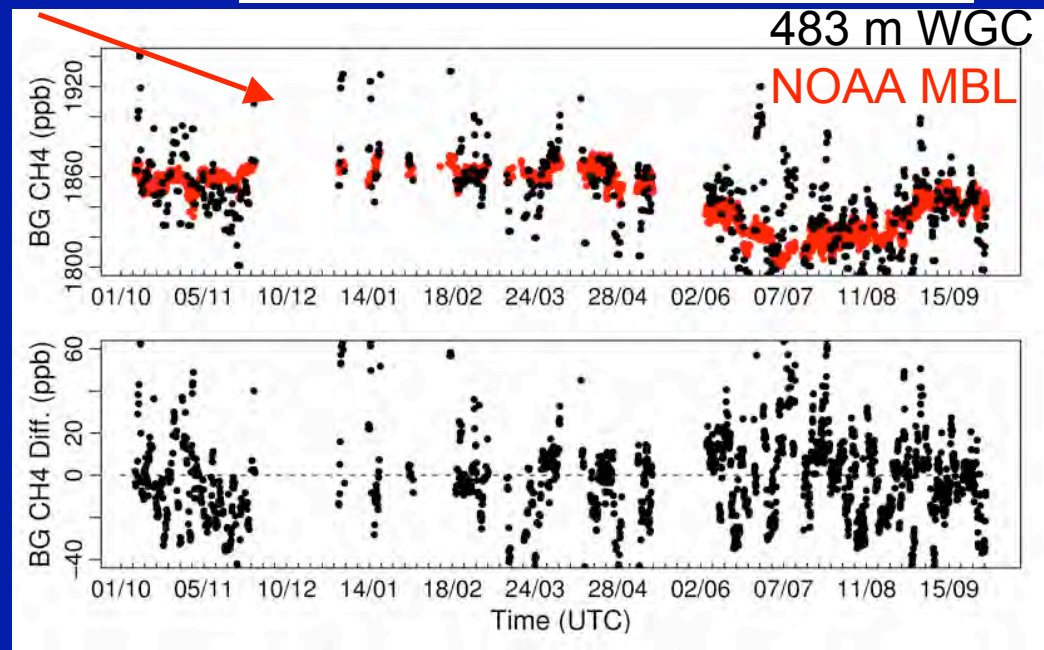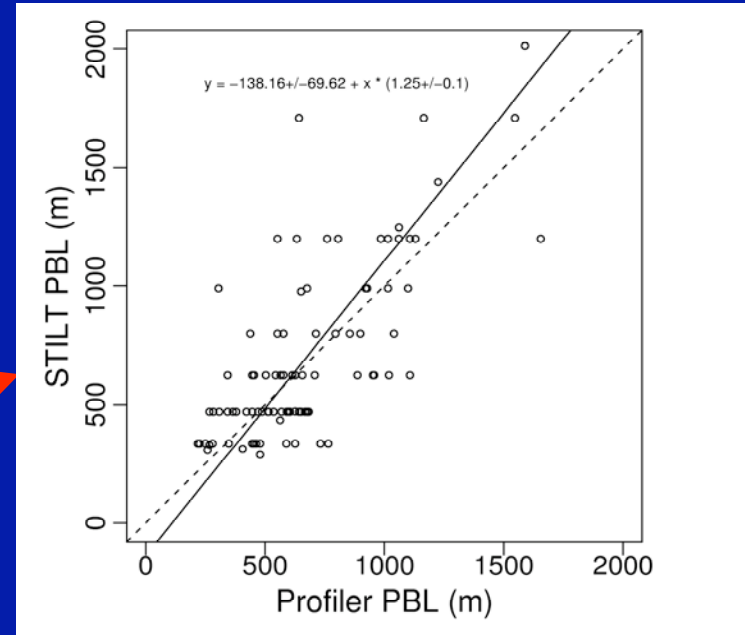
Predicted vs. Measured CH$_4$ By Season

- Scatter approximately consistent with estimated uncertainties
- CH$_4$ emissions appear under-estimated in CA inventory for winter and spring periods

- Fire signal clearly visible in June 2008
  - Exclusion of fires CH$_4$ suggests assumed inventory emissions approximately correct for summer period
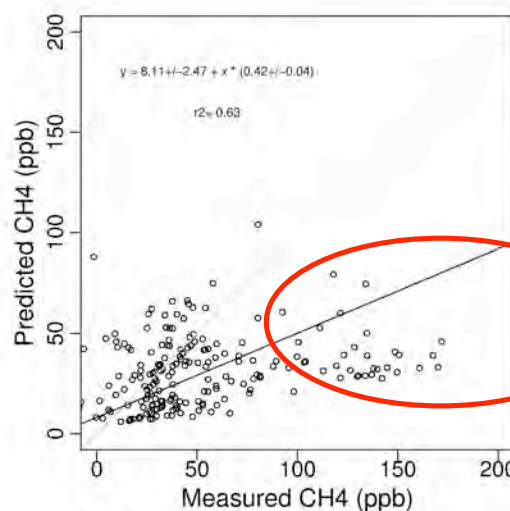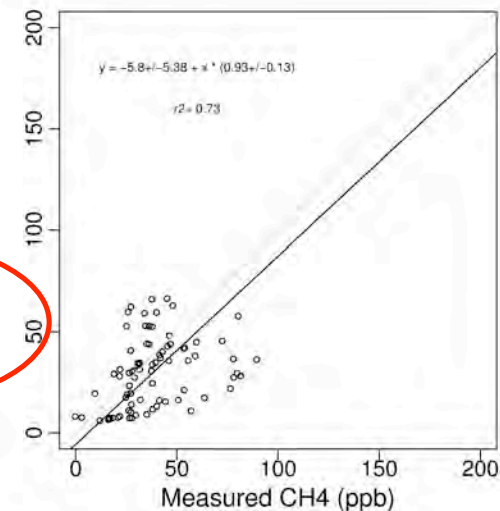

Oct-Dec, 2007
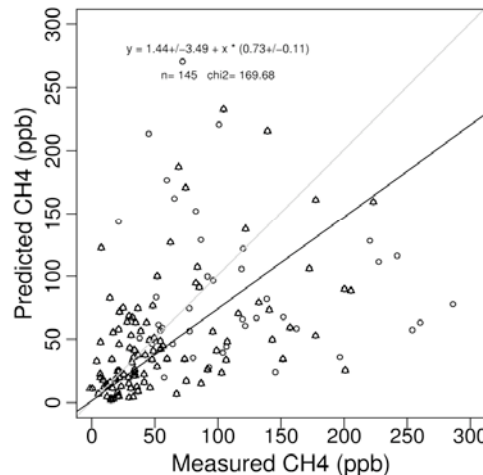
Jan-Mar, 2008
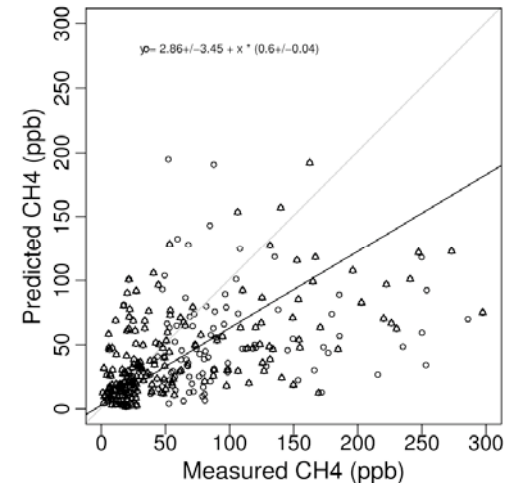
June, 2008

June w/o Fire

Estimated CH$_4$ Emissions (MMT CO$_{2equiv}$)

• Baysian estimate of scaling factor for each emission source or region (*a priori* errors assigned at 30%)

• Source analysis: only livestock significantly different from prior (x 1.6 ± 0.15)

• Region analysis:
  - only regions near WGC tower have errors reduced
  - regions 7 & 8 are larger than prior, consistent with source analysis

 (Zhao et al., 2009, Journal Geophys. Res.)

Wetland Landfill Livestock Nat Gas. Petro. Crops
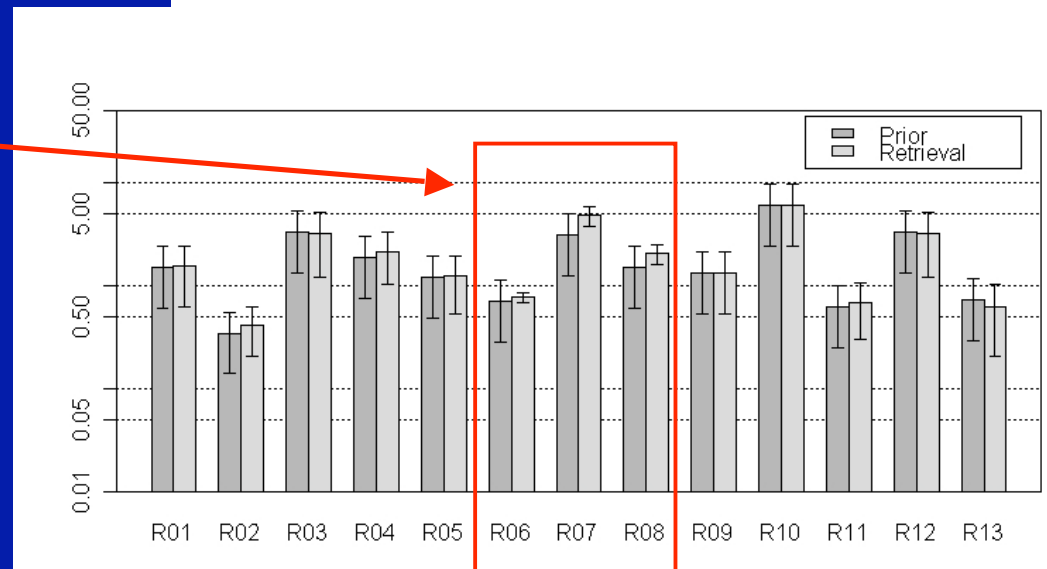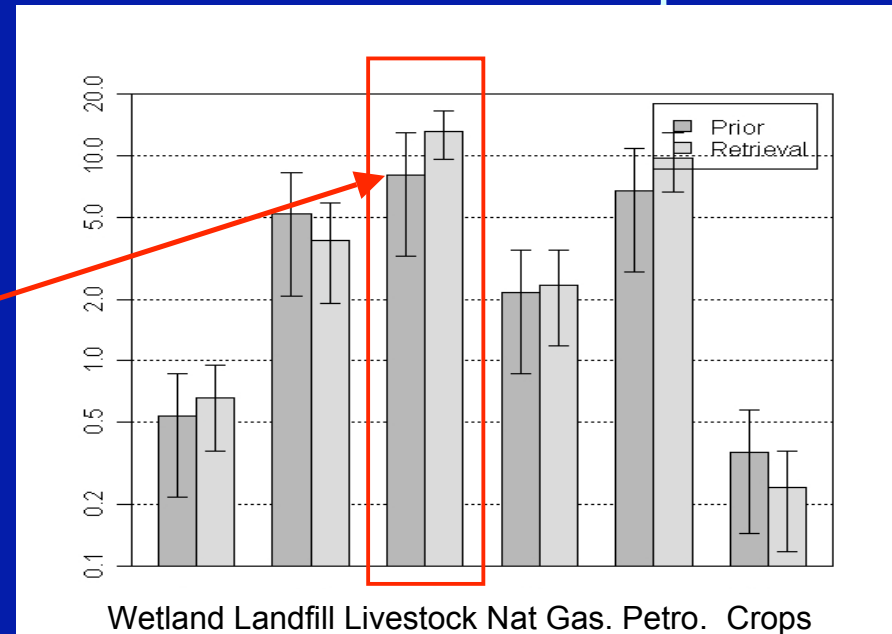
Winter-Spring Measured and Predicted N$_2$O

- N$_2$O flask data is sparse compared to *in situ* CH$_4$

- Slopes vary with season

  - Fall 2007 slope near unity: approximate agreement with inventory emissions

  - Spring: slope ~ 1/2, suggesting actual emissions ~ 2 x inventory

Oct-Dec, 2007 — y = 0.29+/-0.13 + x * (0.9+/-0.32)

Jan-Mar, 2008 — y = 0.19+/-0.08 + x * (0.4+/-0.12)
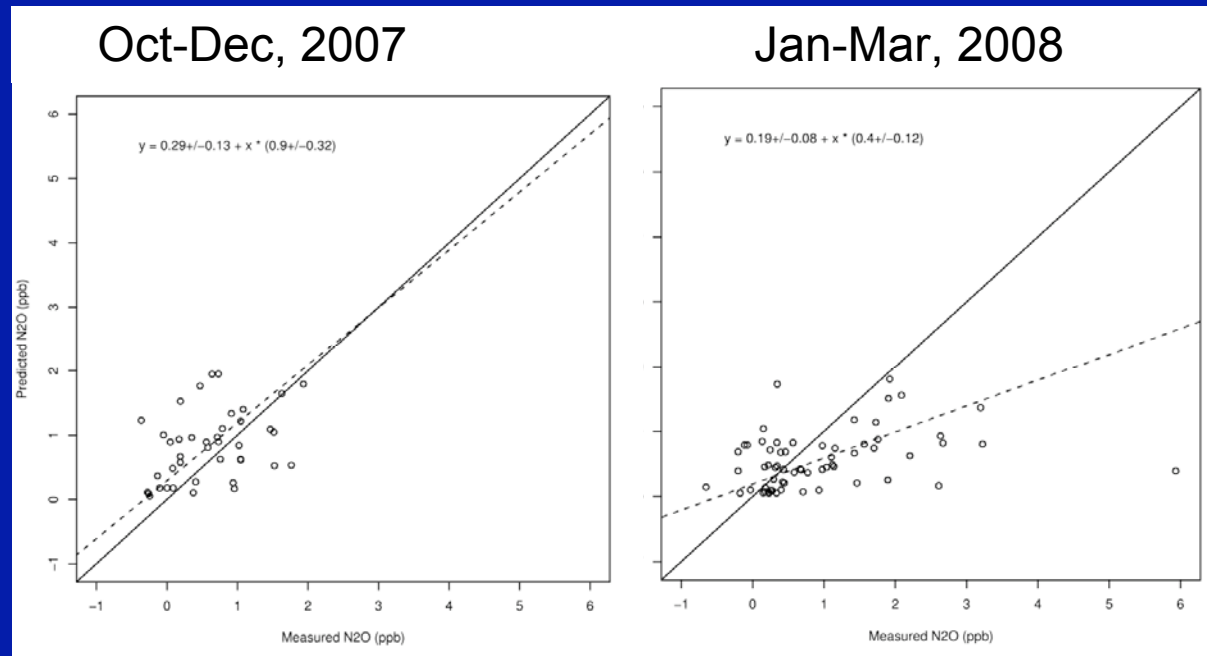
Measurement Network Design

- Estimate effect of seven (3 valley, 4 costal) tower network

- WRF-STILT footprints show predicted regional coverage for Oct, 2007

- Psuedo-data generated from footprints, inventory CH4 emissions, and 32% random noise as estimated above

- Regional inverse estimates of posterior scaling factors show reduction in uncertainties for most regions
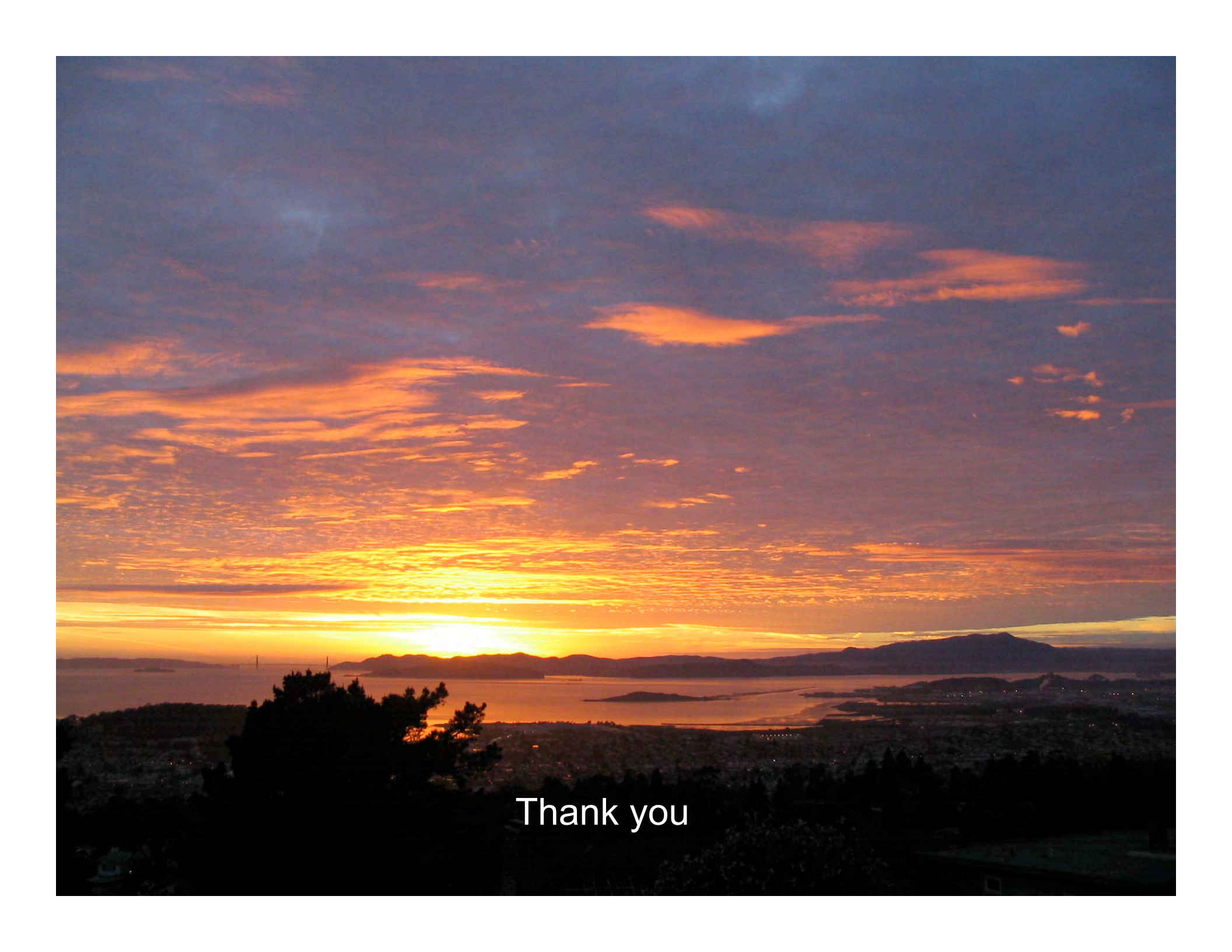
  (Fischer, et. al, 2009, CEC)
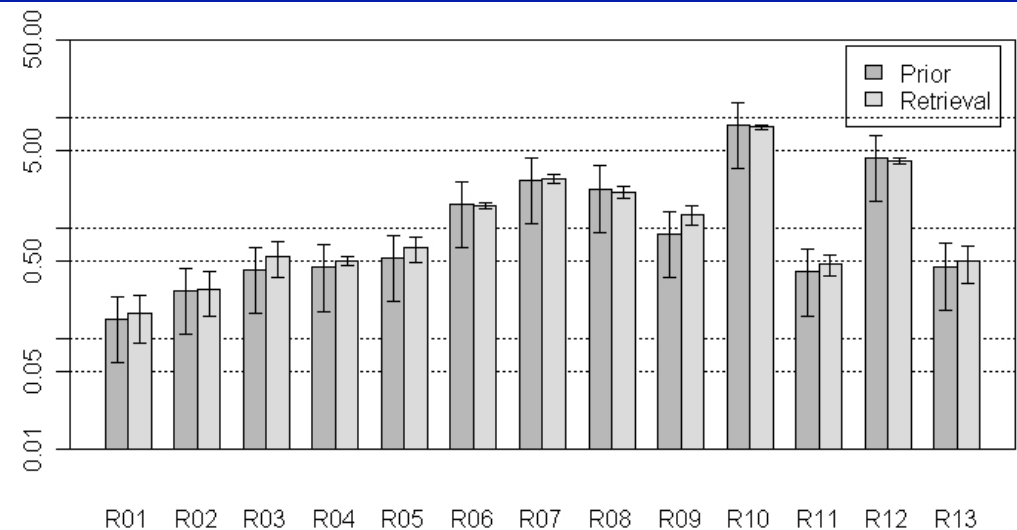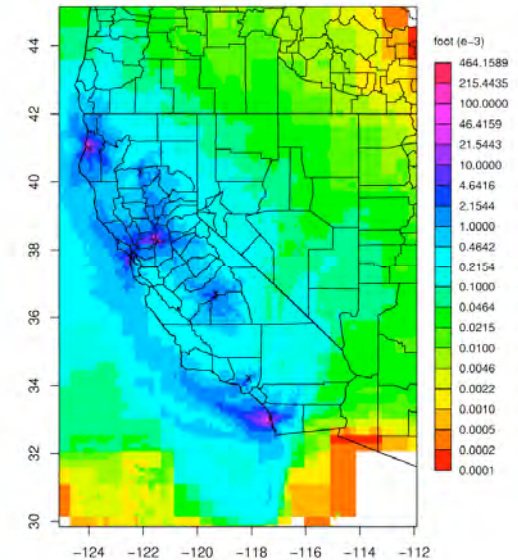
Airborne Greenhouse Gas Survey (AGES)

- Kalscott-LBNL DOE-SBIR to survey regional GHGs sources from small aircraft

- June, 2008 and March, 2009 campaigns from Napa CA

- Instruments
  - Picarro CO_2/CH_4
  - Aerolaser UV Florescence CO
  - NOAA -12 Flask Package

- Observations of CO_2 over Sacramento urban area and Central Valley agriculture
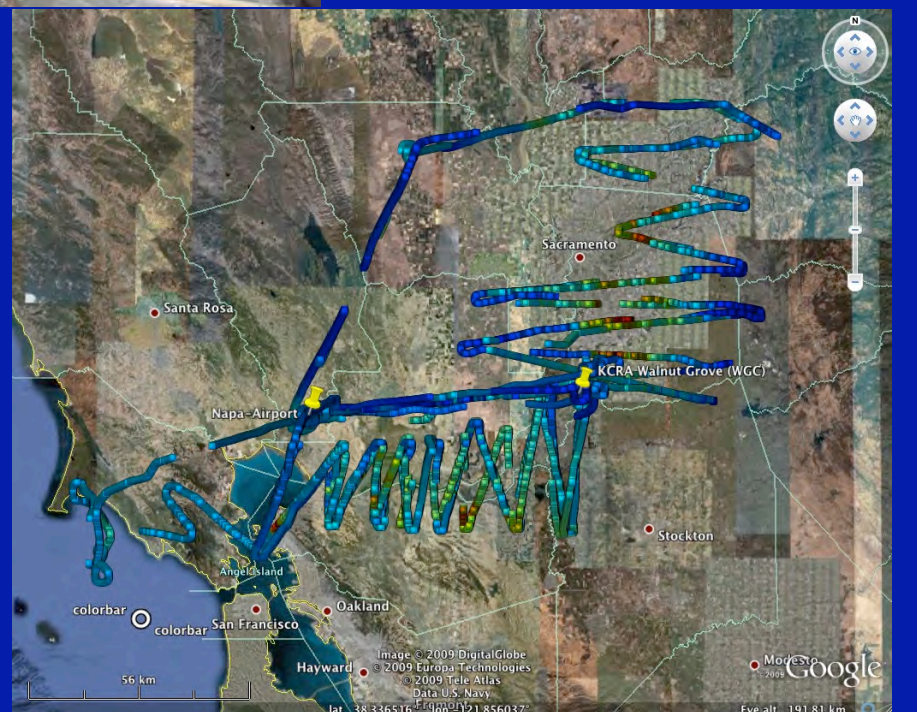
Conclusions

- Careful attention to uncertainties essential for quantitative emission inventory assessment

  - Measurement errors are now small compared to other sources

- Meteorological uncertainty assessment requires multiple measurement sites and methods (e.g., wind profilers, tracer gases)

- Initial inverse estimates suggest:

  - CH_4 emissions underestimated in Central CA Valley region

  - N_2O emissions also underestimated but vary significantly with season

- Even tall-tower measurements in valley appear to only constrain ~ 100-200km region surrounding tower (483 m height decouples)

- Network of towers required to capture regional emissions from California

Thank you